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IoT-Based Smart Agriculture Monitoring System

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Abstract: *Smart agriculture is an emerging concept because IoT sensors are capable of providing information about agriculture fields and then acting based on user input. In this Project, it is proposed to develop a Smart agriculture System that uses the advantages of cutting-edge technologies such as Arduino, IOT, and Wireless Sensor Networks. The paper aims at making use of evolving technology i.e. IOT and smart agriculture using automation. Monitoring environmental conditions is the major factor to improve yield of the efficient crops. The feature of this paper includes the development of a system that can monitor temperature, humidity, moisture, and even the movement of animals which may destroy the crops in agricultural fields through sensors using Arduino board and in case of any discrepancy send a WhatsApp notification as well as a notification on the application developed for the same to the farmer's smartphone using Wi-Fi/4G/5G. The system has a duplex communication link based on a cellular Internet interface that allows for data inspection and irrigation scheduling to be programmed through an Android application. Because of its energy autonomy and low cost, the system has the potential to be useful in water-limited geographically isolated areas.*

Keywords: *Smart agriculture*

I. INTRODUCTION

As the world is trending into new technologies and implementations it is a necessary goal to trend up in agriculture also. Agriculture is considered the basis of life for the human species as it is the main source of food grains and raw materials. Where it plays a vital role in the growth of the Country's economy. It also provides large ample employment opportunities to the people. Growth in the agriculture sector is necessary for the development of the economic condition of the country. Unfortunately, many farmers still use the traditional methods of farming which results in low yielding of crops and fruits. But wherever automation had been implemented and human beings had been replaced by automatic machinery, the yield has been improved. Hence there is a need to implement modern science and technology in the agriculture sector for increasing the yield. Farming and agriculture are the basis of human technology and hold a tremendous role in increased production and decreased extra manpower. Using an IOT sensor network following operations can be done: Automatic plant irrigation system Rain Alarm, and Soil moisture detector circuit.

Traditional agriculture practices have been in use for centuries, and they involve a lot of manual labor and guesswork. Farmers must rely on their experience and observations to decide when to plant, water, and harvest their crops. However, with the advancement of technology, there has been a shift towards using smart agriculture systems that are more efficient and accurate.

II. LITERATURE SURVEY

"IoT-based smart agriculture monitoring system using wireless sensor network and cloud computing" by R. Uthayakumar, V. Prasanna Venkatesan, and R. Ganapathy. This paper proposes an IoT-based smart agriculture monitoring system that uses wireless sensor networks and cloud computing. The system can monitor various parameters such as temperature, humidity, soil moisture, and light intensity in real time.

"Smart Agriculture Monitoring System using IoT and Machine Learning Techniques" by T. Jayanthi, M. Indira Priyadharshini, and S. M. Kannan. This paper proposes an IoT-based smart agriculture monitoring system that uses machine learning techniques to predict crop yield. The system can monitor various parameters such as temperature, humidity, and soil moisture.

"IoT-Based Smart Agriculture Monitoring System for Improving Crop Yield" by N. R. Amrutha and K. Divya. This paper proposes an IoT-based smart agriculture monitoring system that uses sensors to monitor various parameters such as temperature, humidity, and soil moisture. The system also provides alerts and notifications to farmers based on the data collected.

"IoT-Based Smart Agriculture Monitoring System Using Raspberry Pi" by M. A. Karim and M. M. Rahman. This paper proposes an IoT-based smart agriculture monitoring system that uses Raspberry Pi as the main controller. The system can monitor various parameters such as temperature, humidity, soil moisture, and light intensity. The system also provides alerts and notifications to farmers based on the data collected.

"Design and Implementation of an IoT-Based Smart Agriculture Monitoring System" by F. A. Anjum, H. Ahmad, and N. Ahmad. This paper proposes an IoT-based smart agriculture monitoring system that uses sensors to monitor various parameters such as temperature, humidity, soil moisture, and light intensity. The system also provides alerts and notifications to farmers based on the data collected.

III. METHODOLOGY

- **CropX:** CropX is an IoT-based soil monitoring system that uses wireless sensors to collect data on soil moisture, temperature, and electrical conductivity. This data is then analysed using machine learning algorithms to provide insights into crop growth and health.
- **Taranis:** Taranis is an AI-powered crop monitoring system that uses high-resolution imagery and machine learning algorithms to detect and diagnose crop issues such as pests, diseases, and nutrient deficiencies.
- **Trimble:** Trimble offers an IoT-based precision agriculture system that includes a range of sensors and devices to monitor soil moisture, weather conditions, and crop growth. The system also includes software tools for data analysis and decision-making.
- An IoT-based smart agriculture system can perform several functions to help farmers optimize their farming practices. Here are some of the key functions that an IoT-based smart agriculture system can perform:
- **Soil Monitoring:** Soil moisture sensors can be used to monitor the moisture levels in the soil, allowing farmers to adjust irrigation schedules and optimize water usage.
- **Climate Monitoring:** Climate sensors can be used to monitor temperature, humidity, and other environmental factors, allowing farmers to adjust their farming practices based on current conditions.
- **Crop Health Monitoring:** IoT-based smart agriculture systems can use sensors to monitor the health of the crop, including its growth rate and nutrient levels, allowing farmers to adjust fertilizer and irrigation schedules as needed.
- **Irrigation Control:** IoT-based smart agriculture systems can automate irrigation systems, ensuring that crops receive the appropriate amount of water at the right time.
- **Harvest Prediction:** IoT-based smart agriculture systems can use data analytics to predict harvest yields, allowing farmers to plan their resources and optimize their harvest schedules.
- **Equipment Monitoring:** IoT-based smart agriculture systems can use sensors to monitor the performance of equipment, alerting farmers to potential maintenance issues before they become serious.
- **Remote Control:** IoT-based smart agriculture systems can be remotely controlled and monitored through a mobile app or web portal, allowing farmers to check on their crops, Agriculture field and adjust settings from anywhere.

IV. SYSTEM ARCHITECTURE

- **Sensor Data Collection:** The system collects data from various sensors installed in the farm, including soil moisture sensors, temperature sensors, humidity sensors, and other environmental sensors. These sensors transmit the data wirelessly to the cloud-based platform.
- **Data Processing:** The system processes the collected data and analyses it to provide meaningful insights to farmers. This includes identifying patterns, trends, and anomalies in the data that could indicate potential problems, such as low soil moisture levels, high temperature, or pest infestation.

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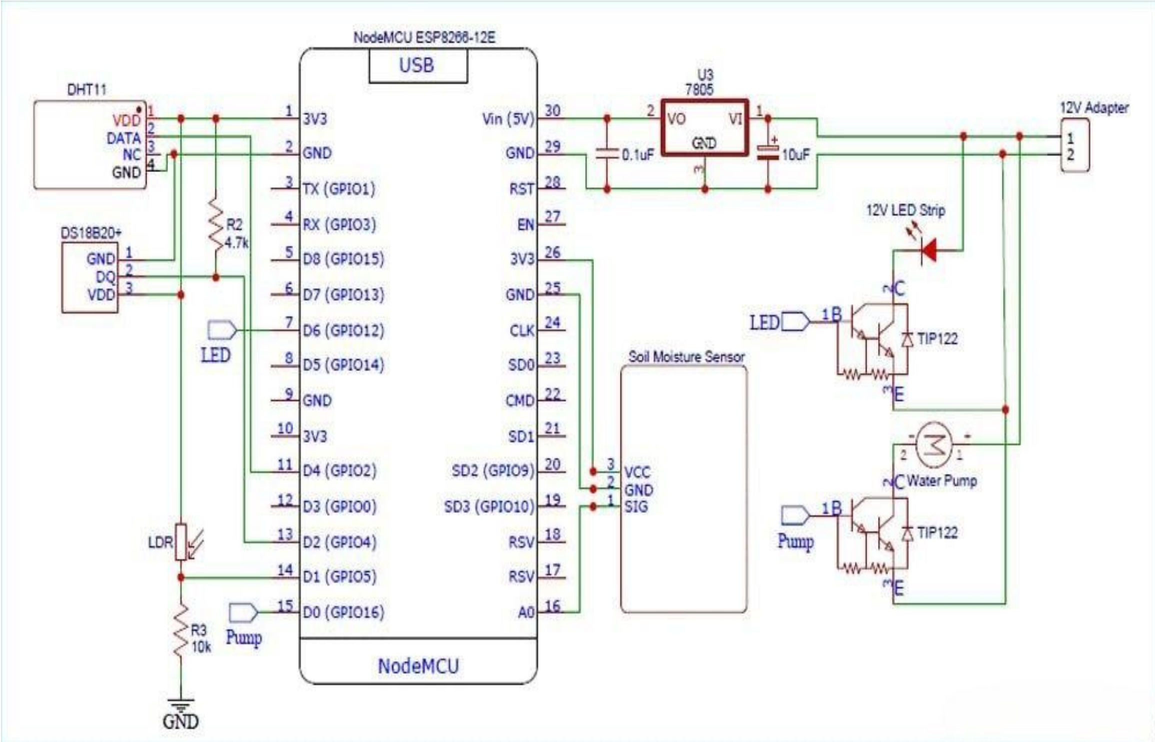

- **Data Visualization:** The system presents the analysed data in an easily understandable format using graphs, charts, and tables. Farmers can access this data through a web-based dashboard or a mobile application.
- **Alerts and Notifications:** The system sends alerts and notifications to farmers when there are issues that require their attention. For example, the system may send a notification to the farmer's smartphone when the soil moisture level drops below a certain threshold or the temperature exceeds a specific limit.
- **Automated Decision-making:** The system can automate decision-making based on the collected data. For example, the system may turn on irrigation systems or adjust fertilizer levels automatically based on the soil moisture and nutrient levels.
- **System Integration:** The system can integrate with other farming technologies, such as drones or robotic farming equipment, to provide a more comprehensive view of the farm's conditions and enable automated farming practices.
- **Data Storage:** The system stores the collected data in a secure and scalable database for future reference and analysis.
- **Sensors and Actuators:** These are the devices that collect data on various parameters such as temperature, humidity, soil moisture, and light intensity. Sensors can also be used to detect the presence of pests, diseases, and weeds. Actuators are devices that perform specific actions such as controlling irrigation, fertilization, and lighting systems.
- **IoT Gateway:** The IoT gateway acts as a bridge between the sensors/actuators and the cloud server. It collects the data from the sensors and sends it to the cloud server for processing and storage. The IoT gateway can also perform some basic data processing and filtering tasks.
- **Cloud Server:** The cloud server is responsible for storing and processing the data collected by the sensors. It provides a platform for data analysis, visualization, and decision-making. Cloud servers can also provide remote access to the system for farmers, researchers, and other stakeholders.
- **Data Analytics and Machine Learning:** Data analytics and machine learning techniques are used to process and analyse the data collected by the sensors. This can provide valuable insights into crop growth, yield prediction, and pest/disease detection. Machine learning can also be used to develop predictive models that can optimize farming practices.

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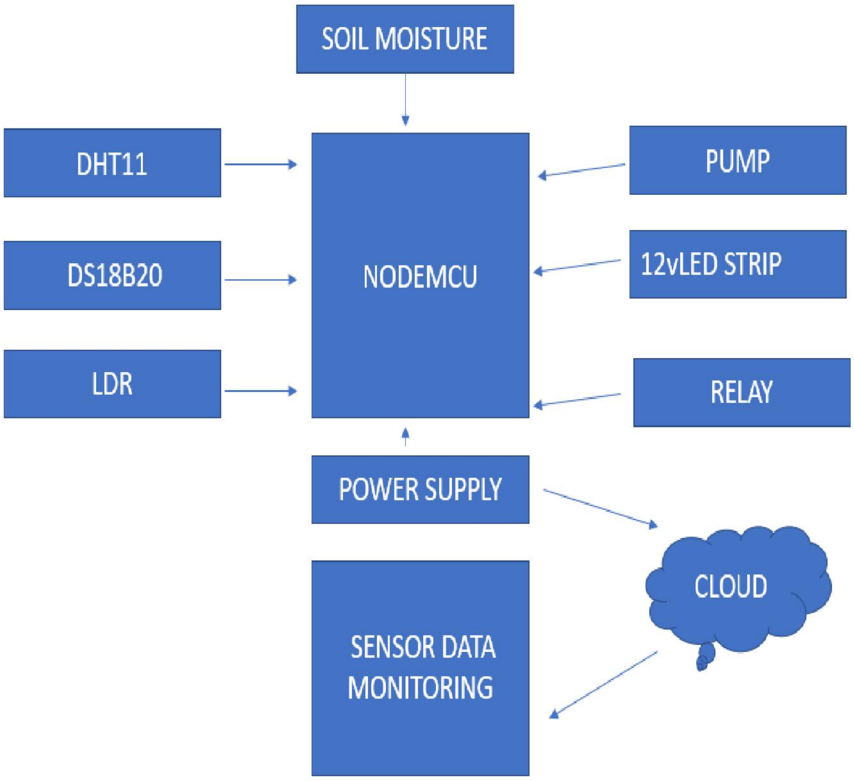
- **Mobile/Web Application:** A mobile or web application can be developed to provide farmers with real-time information on crop growth and health. The application can also provide alerts and notifications to farmers based on the data collected by the sensors. Farmers can also use the application to remotely control the irrigation, fertilization, and lighting systems.



V. DESCRIPTION OF MODULE OPERATION

Main Module

- Responsible for the overall operation of the system.
- Initializes the system and connects to the Wi-Fi network.
- Sets up the sensors and other hardware components.
- Reads the sensor data and sends it to the cloud-based platform.
- Receives commands from the cloud-based platform and performs automated decision-making based on the received data.
- Displays the sensor data and system status on an LCD screen.
- Sends alerts and notifications to farmers via email or SMS.
- Stores the sensor data in a database for future reference and analysis.
- Continuously monitors the system and sensor data.

Sensor Module

- Responsible for reading the sensor data and storing it in variables.
- Includes soil moisture, temperature, humidity, and other environmental sensors.
- Cloud-Based Platform Module.
- Responsible for receiving the sensor data and commands from the IoT device.
- Includes the Adafruit IO library for sending and receiving data from the cloud-based platform.

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Automated Decision-Making Module:

- Responsible for performing automated decision-making based on the received commands and sensor data.
- Includes logic for turning on/off irrigation systems or adjusting fertilizer levels.

LCD Display Module:

- Responsible for displaying the sensor data and system status on an LCD screen.
- Includes the Adafruit SSD1306 library for interfacing with the LCD screen.

Alert/Notification Module:

- Responsible for sending alerts and notifications to farmers via email or SMS when there are issues that require their attention.
- Includes the SMTP and SMS libraries for sending emails and text messages.

Database Module:

- Responsible for storing the sensor data in a database for future reference and analysis.
- Includes a database management system such as MySQL or MongoDB.
- The operation of the system is as follows:
- The main module initializes the system and connects to the Wi-Fi network.
- The sensor module reads the sensor data and stores it in variables.
- The cloud-based platform module receives the sensor data and commands from the IoT device using the Adafruit IO library.
- The automated decision-making module performs automated decision-making based on the received commands and sensor data.
- The LCD display module displays the sensor data and system status on an LCD screen.
- The alert/notification module sends alerts and notifications to farmers via email or SMS when there are issues that require their attention.
- The database module stores the sensor data in a database for future reference and analysis.

The system continuously monitors the sensors and repeats steps 2-7.

VI. TEST RUN PROCEDURES AND RESULTS

Step 1: Adafruit IO Setup

Adafruit IO is an open data platform that allows you to aggregate, visualize, and analyse live data on the cloud. Using Adafruit IO, you can upload, display, and monitor your data over the internet, and make your project IoT-enabled. We can control motors, read sensor data, and make cool IoT applications over the internet using Adafruit IO.

To use Adafruit IO, first, you have to create an account on Adafruit IO. To do this, go to the Adafruit IO website and click 'Get started for Free' on the top right of the screen.

After finishing the account creation process, log in to your account and click on 'View AIO Key' on the top right corner to get your account username and AIO key. When you click on 'AIO Key,' a window will pop up with your Adafruit IO AIO Key and username. Copy this key and username. You'll need it later in your code. Now, after this, you need to create a feed. To create a feed, click on 'Feed.' Then click on 'Actions,' you will see some options, from them, click on 'Create a New Feed.

After this, a new window will open where you need to input the Name and Description of your feed. Writing a description is optional. Click on 'Create,'; after this, you will be redirected to your newly created feed. For this project, we created a total of eight feeds for the Water pump, LED Strip, moisture data, Temperature, Humidity, Weather data, and Soil Temperature. Follow the same procedure as above to create the rest of the feeds. After creating feeds, now we will create an Adafruit IO dashboard to show all of these feeds on a single page. For that, first, create a dashboard and then add all these feeds to that dashboard.

To create a dashboard, click on the Dashboard option and then click on the 'Action,' and after this, click on 'Create a New Dashboard. In the next window, enter the name for your dashboard and click on 'Create' As our dashboard is created, now we will add our Blocks to the dashboard.
To add a Block, click on the 'Gear' in the top right corner and then click on 'Create New Block'. First, we will add two toggle buttons blocks to turn ON/OFF the LED Strip and Water Pump manually, then four sliders to display Temperature, Humidity, Soil Temperature, and Moisture Value, and lastly, two Graph blocks to display the last 30-day Moisture and Soil Temperature Data.
To add a button on the dashboard, click on the Toggle block. In the next window, it will ask you to choose the feed, so click on LED feed. After this, follow the same procedure to add the rest of the blocks. After adding all the blocks, my dashboard looks like this You can edit your dashboard by clicking on the settings buttons.

Step 2. Programming Node MCU for Smart Agriculture System:
Here we are explaining some important parts of the code. The code uses the **DallasTemperature**, **OneWire, Adafruit_MQTT, ArduinoJson**, and **DHT.h** libraries.
After installing the libraries to Arduino IDE, start the code by including the required
Then set up the Adafruit IO feeds for storing the sensor data and controlling LED and water pump. In my case, I have defined four feeds to store different sensor data
namely: Soil Temperature, Temperature, Humidity, and Moisture, one feed for displaying Weather data, and two feeds to control LED Strip & Water Pump.
Now inside the ***setup()*** function, initialize the Serial Monitor at a baud rate of 9600 for debugging purposes. Also Initialize the DHT sensor, and DS18B20 sensor with the ***begin()*** function.
Now comes the ***void loop()***. This is where all the tasks are performed. So, in this loop, first, we will get the weather forecast data from OpenWeatherMap API, then we will read the sensors data and in the last step, we will publish all this data on the Adafruit IO dashboard.

Step 3. Reading the Sensor Data:
Now after getting the weather data, next we will read all the sensor data. Here we are using the DHT11, DS18B20, LDR, and Soil Moisture Sensor. LDR and soil moisture sensor data will be used to automate the LED strip and water pump. So first we will read the LDR status and if the LDR reading is less than 200, then the LED will be turned on automatically. Similarly, if the soil moisture percentage is less than 35, then the water pump will be turned on.

Step 4. Testing the Smart Farming System:
To test this project, I sprouted some seeds in a plastic tray as shown in the below image.
I mounted the hardware box beside the tray, connected a water pump to a water bottle, and connected the power supply. With this done, it starts monitoring the different parameters like soil moisture, soil temperature, etc. All these reading will be published on Adafruit IO dashboard.

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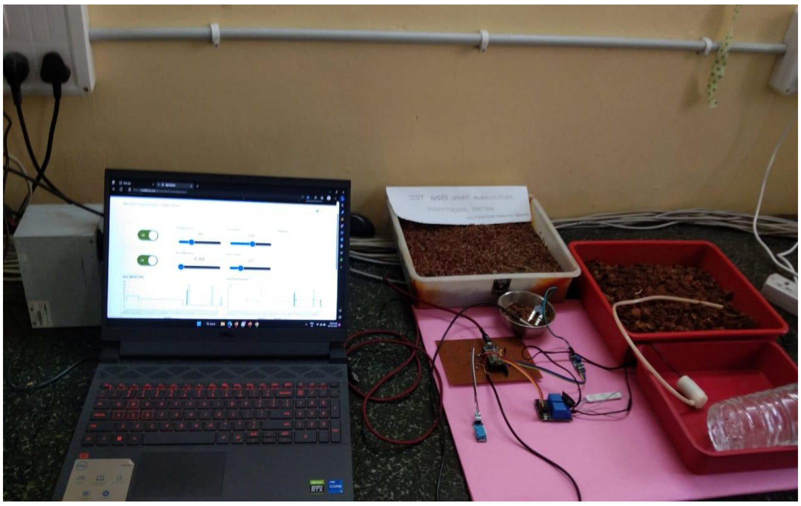
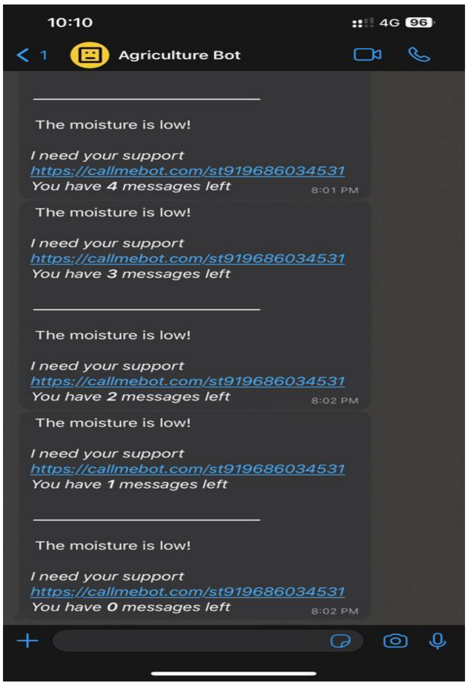


FIG 6.1: MODEL REPRESENTATION



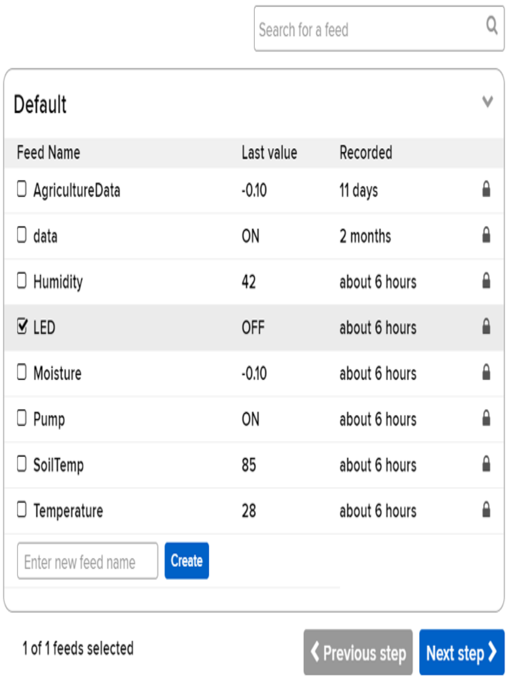


FIG 6.2: WHATSAPP NOTIFICATIONS FIG 6.3: USER SCREEN

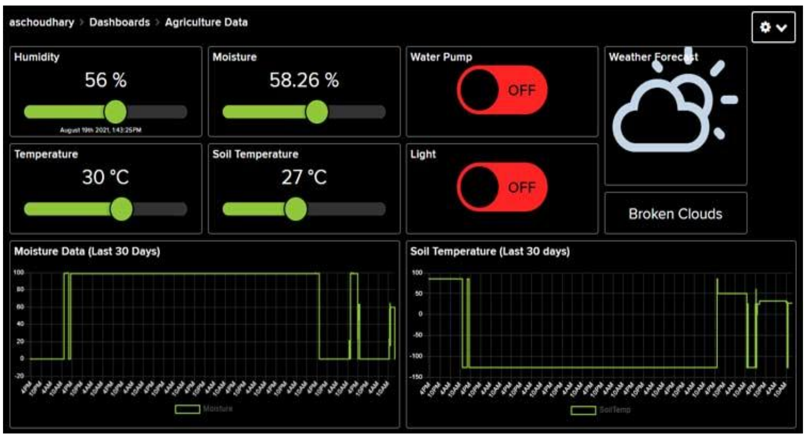


FIG 6.4: ADAFRUIT DASHBOARD

VII. CONCLUSION

An IoT-based smart agriculture monitoring system is a powerful tool for farmers to optimize their farming practices, increase crop yields, and improve overall productivity. The system relies on a network of sensors, cloud-based platforms, and data analytics to provide real-time information on the conditions of the farm, including soil moisture, temperature, humidity, and other environmental factors. The system's real-time data enables farmers to make data-driven decisions about crop management practices, irrigation, and fertilization, among others. Additionally, the system can provide local weather forecasts and alerts on any issues that require the farmer's attention.

However, the success of an IoT-based smart agriculture monitoring system depends on several external and internal factors, including network connectivity, power supply, sensor accuracy, data processing, system complexity, and security. Addressing these limitations can help improve the system's performance and reliability, enabling farmers to make informed decisions and optimize their farming practices.

Overall, an IoT-based smart agriculture monitoring system is a valuable tool that can help farmers overcome the challenges of modern agriculture, reduce waste, and increase efficiency, leading to more sustainable and profitable farming practices

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